(12) UK Patent Application (19) GB (11) 2 194 376 (13) A

(43) Application published 2 Mar 1988

(21) Application No 8716207

(22) Date of filing 9 Jul 1987

(30) Priority data
(31) 61/162824 (32) 10 Jul 1986 (33) JP
61/282757 27 Nov 1986

(51) INT CL⁴
G09G 3/20

(52) Domestic classification (Edition J):
G5C A333 A375 HB

(56) Documents cited
GB 0843490 GB 0732238 GB 0701751
D. G. Fink "Television Engineering" 1952 McGraw-Hill page 443

(58) Field of search
G5C
H4F
Selected US specifications from IPC sub-classes G09F G09G

(71) Applicant
Ricoh Company Ltd

(Incorporated in Japan)

3-6 Nakamagome 1-chome, Ohta-ku, Tokyo, Japan

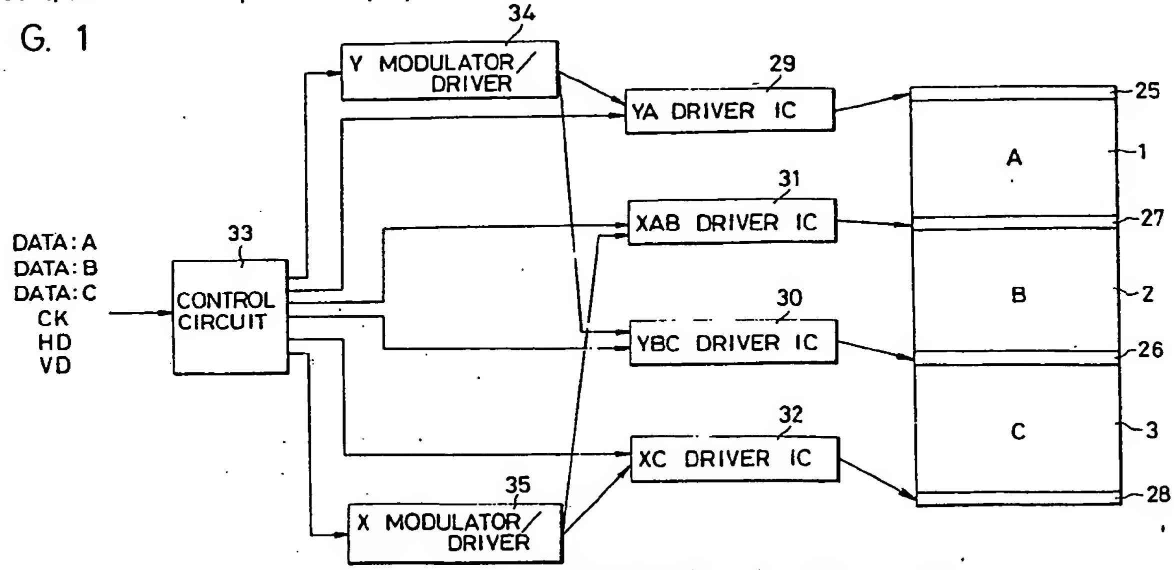
(72) Inventors
Seiichi Oseto
Yoshiyuki Kageyama
Kenji Kameyama

(74) Agent and/or Address for Service
Marks & Clerk,
57–60 Lincoln's Inn Fields, London WC2A 3LS

(54) Method of and device for producing multiple colors

(57) A display device comprises a plurality of stacked light-emitting layers (1,2,3) capable of emitting light of mutually different colors, and a plurality of display electrodes (27,28) and scanning electrodes (25,26) disposed on opposite sides of each of the light-emitting layers. The interposed electrodes (26,27) are shared for driving the light-emitting layers (1,2,3) on opposite sides of those electrodes. A driver circuit energises, on a time basis, the display and scanning electrodes (25–28) to cause the light-emitting layers (1,2,3) sequentially to display respective frame pictures of the colors in response to display signals corresponding to the colors of the layers. The repetition frequency at which the colors of the layers are sequentially varied is selected to be higher than the critical fusion frequency of color stimulus thereby producing a (flicker-free) appearance of mixing the colors. The frequency may be higher than the critical fusion frequency of brightners for a moving multi-colour picture. The invention is applicable to electro-luminescent, fluorescent or plasma displays.

FIG. 1

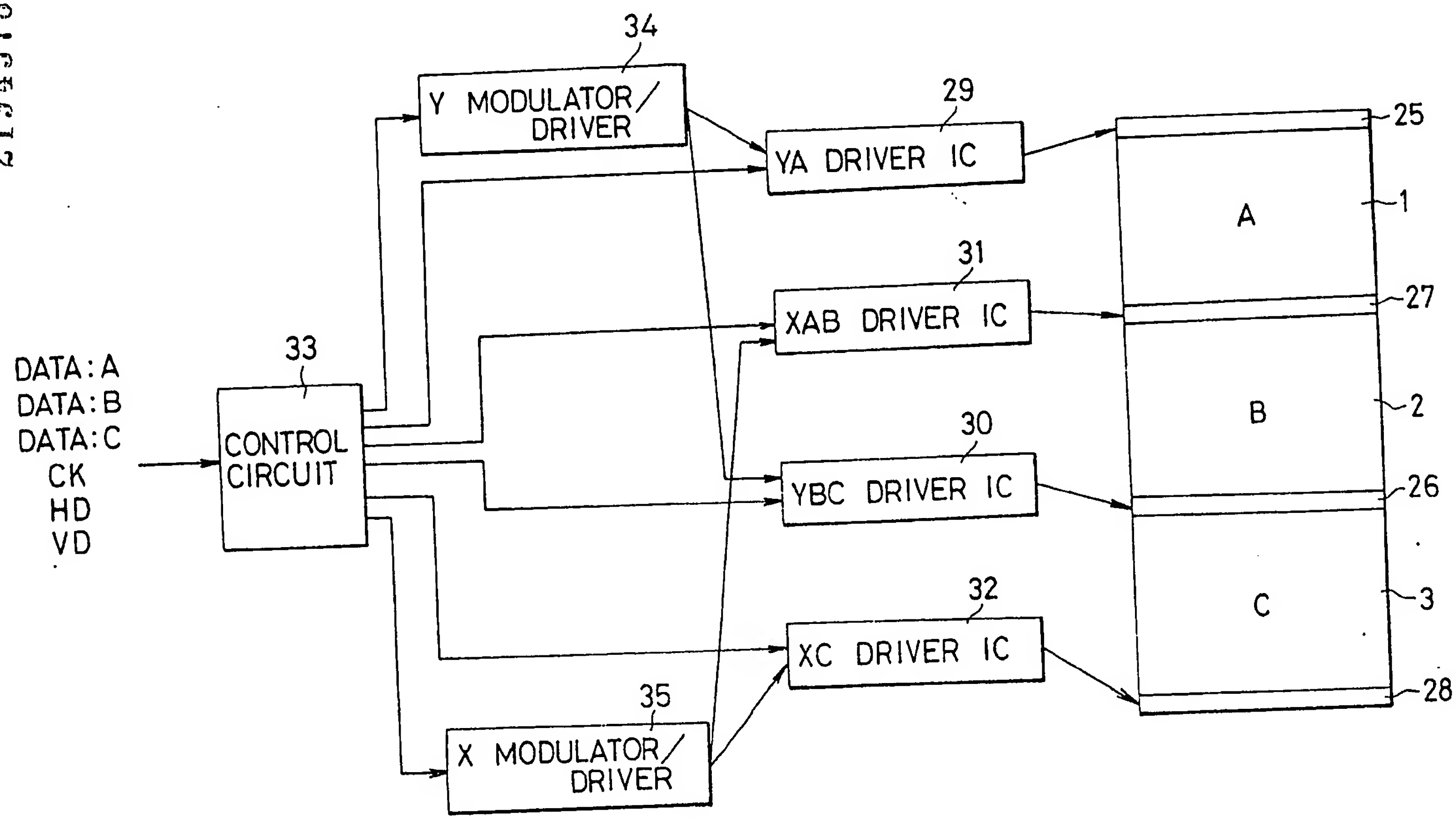


The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

GB 2 194 376 A

2194376

F I G. 1



2194376

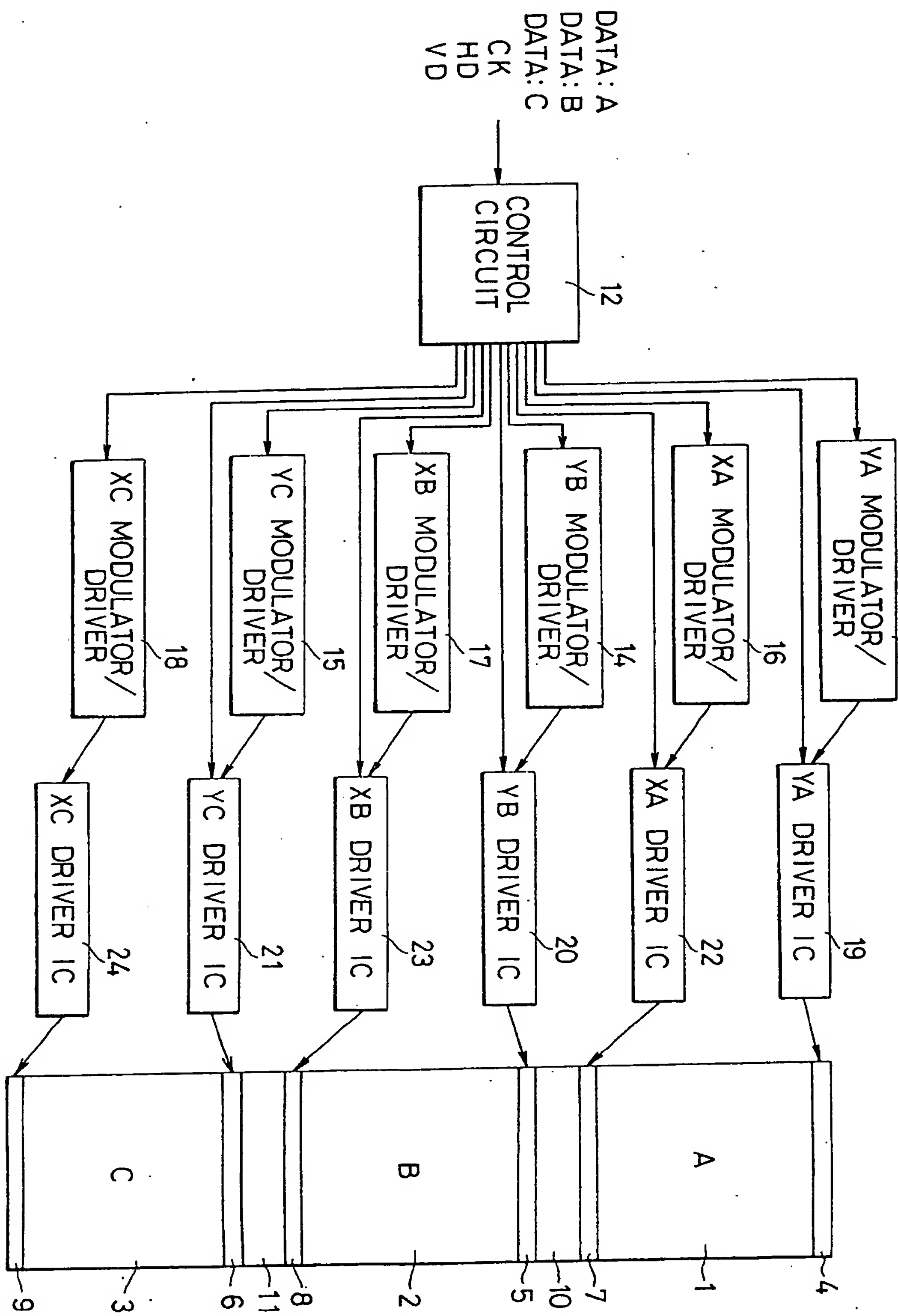


FIG. 2

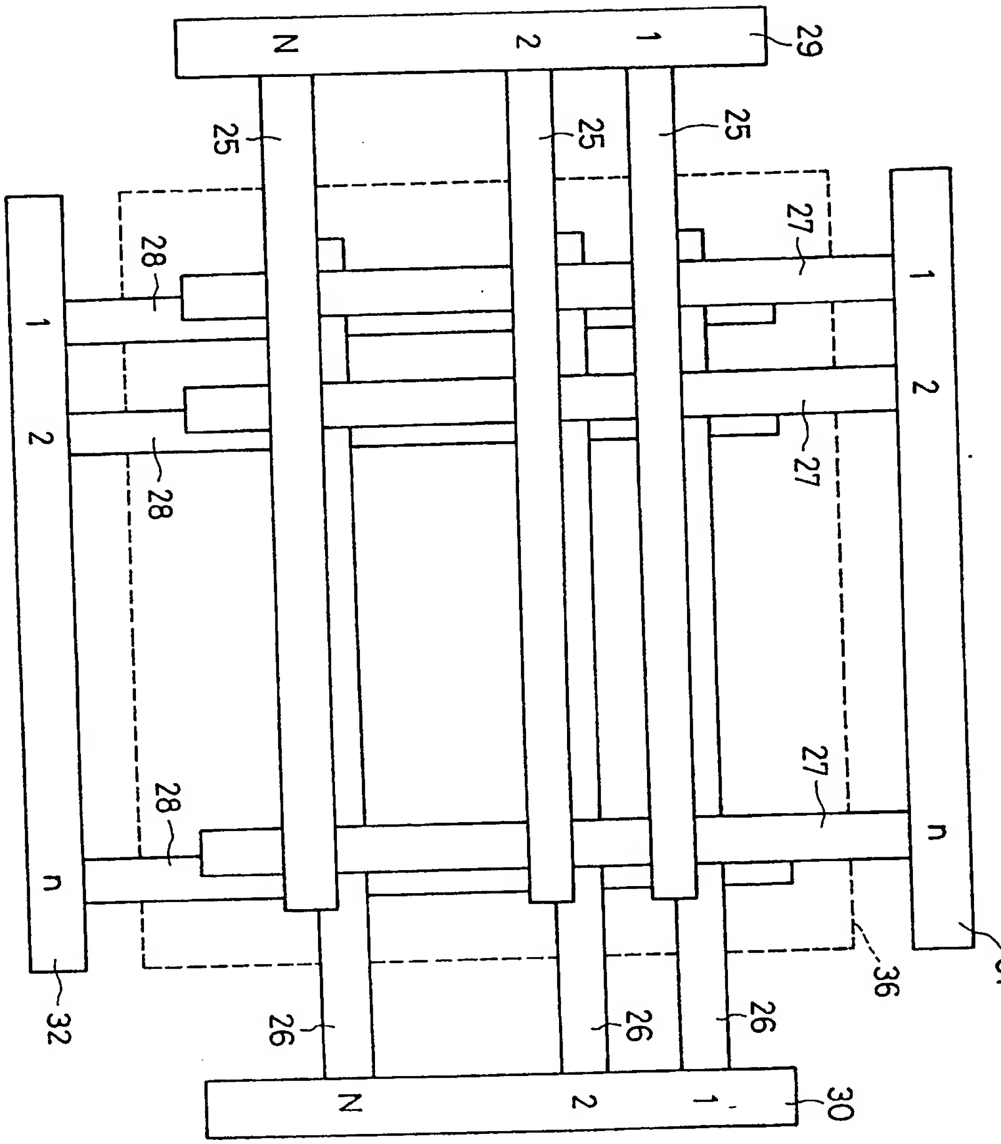
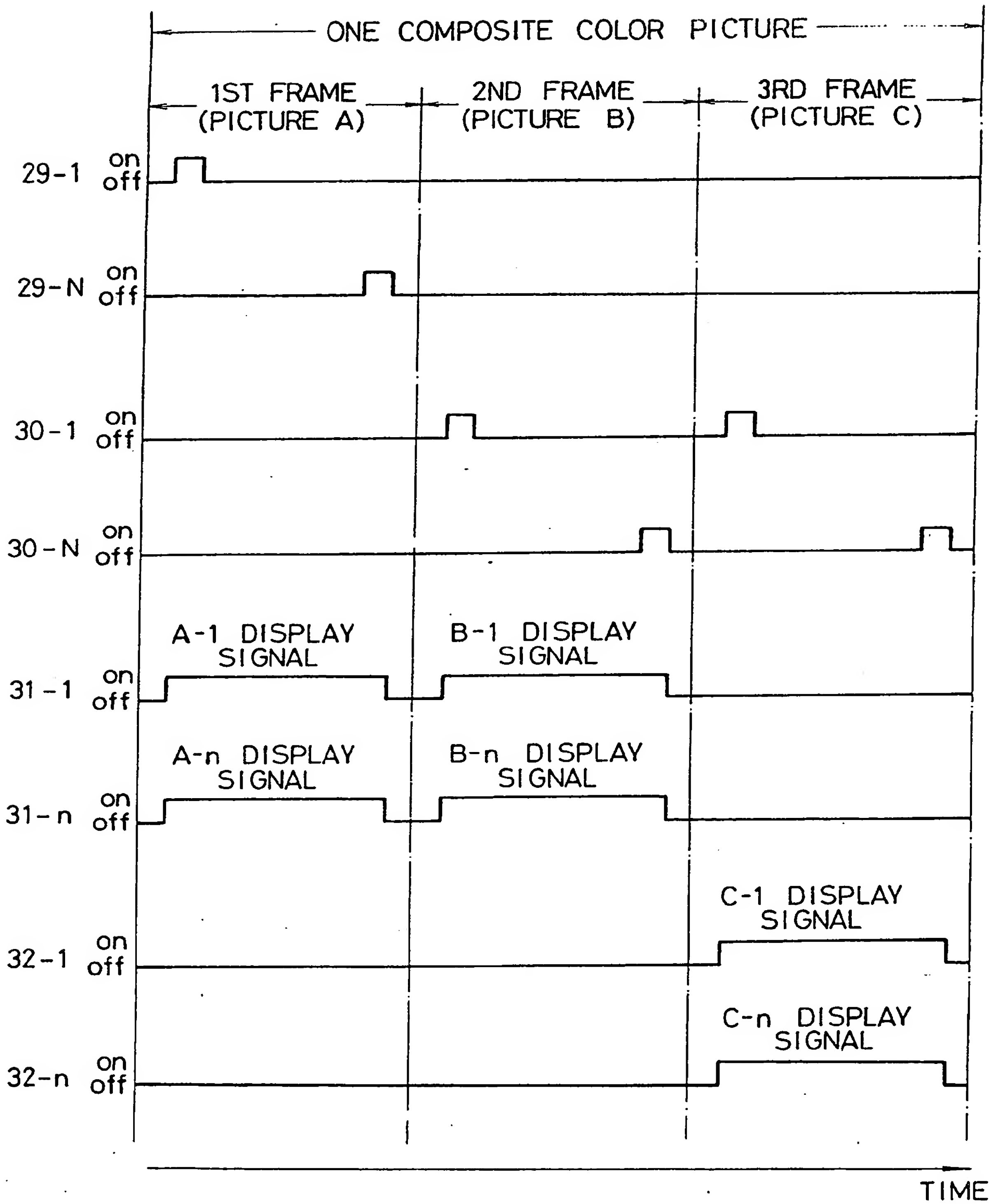
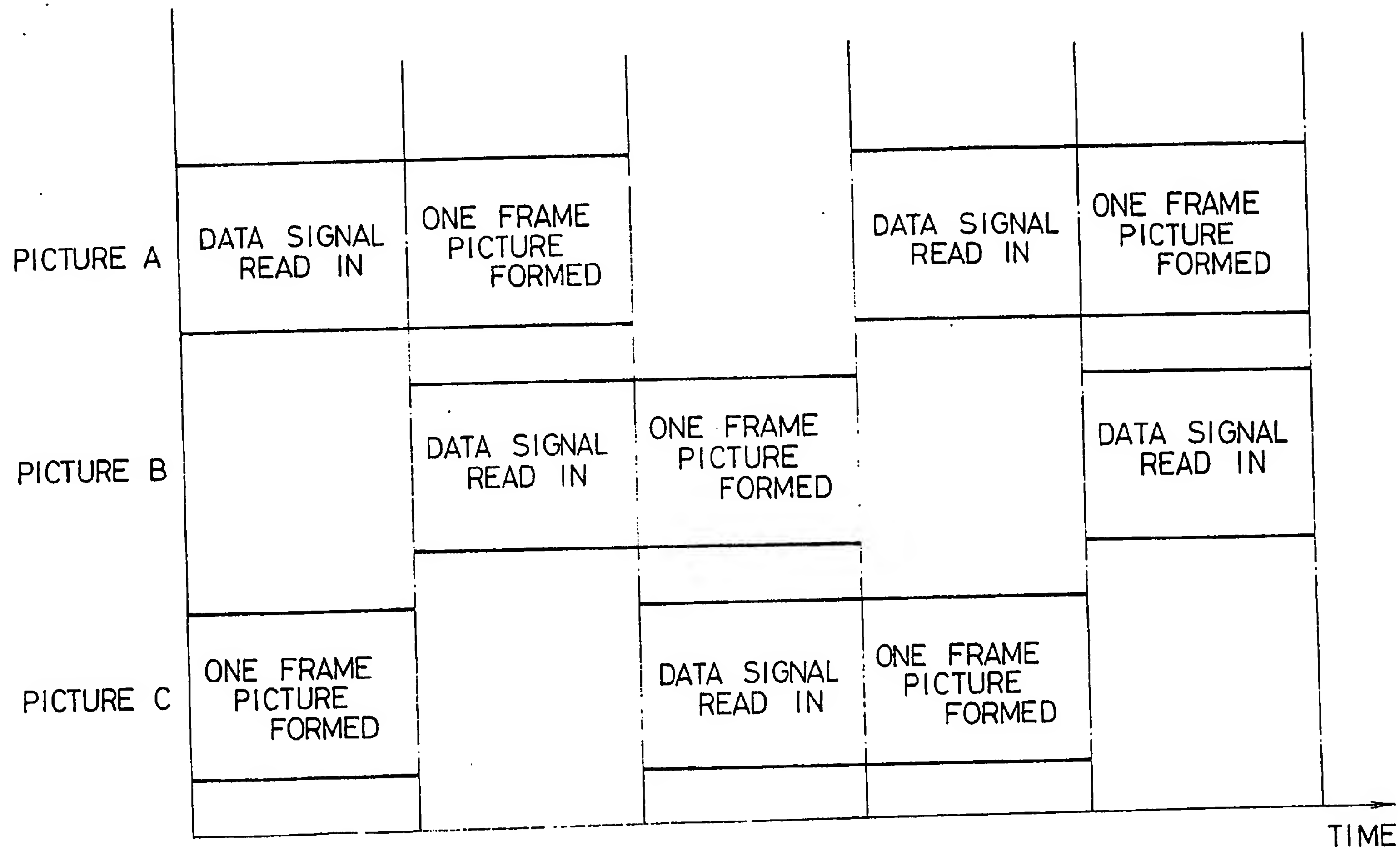


FIG. 3

F I G. 4


ONE COMPOSITE COLOR PICTURE
1ST FRAME (PICTURE A)
2ND FRAME (PICTURE B)
3RD FRAME (PICTURE C)
29-1
on
off
29-N
on
off
30-1
on
off
30-N
on
off
A-1 DISPLAY SIGNAL
B-1 DISPLAY SIGNAL
31-1
on
off
A-n DISPLAY SIGNAL
B-n DISPLAY SIGNAL
31-n
on
off
C-1 DISPLAY SIGNAL
32-1
on
off
C-n DISPLAY SIGNAL
32-n
on
off
TIME

F I G. 5


PICTURE A
PICTURE B
PICTURE C
DATA SIGNAL READ IN
ONE FRAME PICTURE FORMED
DATA SIGNAL READ IN
ONE FRAME PICTURE FORMED
DATA SIGNAL READ IN
ONE FRAME PICTURE FORMED
DATA SIGNAL READ IN
ONE FRAME PICTURE FORMED
DATA SIGNAL READ IN
ONE FRAME PICTURE FORMED
TIME

SPECIFICATION

Method of and device for producing multiple colors

BACKGROUND OF THE INVENTION

The present invention relates to a method of and a device for producing a multiplicity of colors in multicolor display or the like.

All color display devices including conventional cathode-ray tubes are spatial color mixing systems. One of such color mixing systems is a planar color mixing system represented by cathode-ray tubes and color liquid crystal displays. Another color mixing system is a three-dimensional color mixing system as disclosed in Japanese Laid-Open Patent Publication No. 58(1983)-30093, for example.

The color mixing systems of the above types have their own advantages and disadvantages, but suffer serious drawbacks as compared with the black-and-white displays. More specifically, a planar color mixing system has a resolution which is a third as high as the resolution of a black-and-white display. A planar color mixing system of the matrix electrode drive type such as an electro-luminescent display or a liquid crystal display requires three times as many driver circuits and active elements as those of a black-and-while display. A three-dimensional color mixing system has no resolution problem, but also requires three times as many driver circuits and active elements as those of a black-and-while display.

The above shortcomings result from the principles of operation of the respective color mixing systems, and essentially remain unsolved as compared with the black-and-white displays even if display elements are improved.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method of and a device for producing a multiplicity of colors with an increased degree of resolution and a reduced number of active elements.

According to the present invention, there is provided a method of producing a multiplicity of colors on a multicolor display having pixels, comprising the step of sequentially varying the colors of lights from the pixels repeatedly on a time basis in response to display signals at a repetition frequency higher than a critical fusion frequency of color stimulus for thereby enabling the sequentially varying colors to appear to be mixed.

A device for producing a multiplicity of colors includes a plurality of stacked light-emitting layers capable of emitting lights of mutually different colors, a plurality of display electrodes and scanning electrodes disposed on opposite sides of each of the light-emitting layers, those electrodes which are interposed between the light-emitting layers being shared as electrodes for driving the light-emitting layers on opposite sides of those electrodes, and a driver circuit for energizing the display electrodes and the scanning electrodes to cause the light-emitting layers to sequentially display respective frame pictures of the respective colors repeatedly in response to display signals corresponding to the colors of the light-emitting layers, at a repetition frequency higher than a critical fusion frequency of color stimulus, for thereby producing a multicolor picture.

The driver circuit may be arranged to repeat the multicolor picture at a frequency higher than a critical fusion frequency of brightness, for thereby producing a moving multicolor picture.

Research on materials of thin-film electroluminescent displays for multicolor image display has just entered a substantial phase in a few years. Methods of displaying images in multiple colors using combinations of such materials are far behind those for cathode-ray tubes and liquid crystal displays. There has been proposed a method of three-dimensionally producing multiple colors which are mixed in the transverse direction of a display panel composed of stacked light-emitting layers capable of emitting lights of mutually different colors with electrode layers and insulating layers interposed between the light-emitting layers. This method is capable of displaying colored images at better resolution than two-dimensional multicolor image displays represented by the cathode-ray tube. However, the driver system for driving the display panel is highly complex and the number of driver ICs is increased as the display panel contains many layers.

The multicolor producing device according to the present invention comrises a multicolor electroluminescent display composed of two or more, e.g., three electroluminescent layers capable of emitting lights of mutually different colors. The electroluminescent layers are independently driven to three-dimensionally produce multiple colors. The electrode layers disposed between the electroluminescent layers are shared as electrodes for driving these electroluminescent layers held in contact therewith to sequentially form frame pictures of different colors in a serial manner which are mixed on a time basis to reproduce original colors.

As is well known, the human sense of sight is subject to a critical fusion or flicker frequency (CFF) of brightness and a critical fusion or flicker frequency (CFFF) of color stimulus. Generally, CCFF is a fraction of CFFF. Assuming that the time period of one frame formed by each electroluminescent layer is indicated by tF and the time period for the three electroluminescent layers to serially form color-separated pictures is indicated by ΔT (= 3tF),

the requirement of $1/tF > CCFF$ should be met in order to mix the color-separated pictures, of red, green, and blue, for example, formed by the three electroluminescent layers on a time basis to reproduce a colored picture free of color flickering, and the requirement of $1/\Delta T > CFF$ should be met in order to change the reproduced colored picture on a time basis for thereby producing a moving multicolor picture free of motion flickering.

It follows from the above that $1/\Delta T > CFF$ and $1/tF > 3CFF$ should be met in order to prevent color and brightness flickering in images displayed on the electroluminescent display panel composed of three electroluminescent layers.

Since the repetition frequency at which the colors produced by the pixels of the multicolor display device are sequentially varied in response to display signals is selected to be over the critical fusion frequency of color stimulus for color mixing, the resolution of the display can be increased and the number of active elements used can be reduced. The arrangement of the display can be greatly simplified by sharing the electrodes between the light-emitting layers as electrodes for driving the light-emitting layers on opposite sides thereof.

The above and other objects, features and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings in which preferred embodiments of the present invention are shown by way of illustrative example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a device for producing a multiplicity of colors according to the present invention;

FIG. 2 is a block diagram of a conventional device for producing a multiplicity of colors;

FIG. 3 is a schematic view of a portion of the device of the present invention;

FIG. 4 is a timing chart of operation of the device shown in FIG. 1; and

FIG. 5 is a timing chart explanatory of the present invention.

DETAILED DESCRIPTION

FIG. 2 shows, in a block form, a device for carrying out a conventional method of three-dimensionally producing a multiplicity of colors. The device is an electroluminescent (EL) display having a stack of three light-emitting layers 1 through 3 for emitting different colors. Each of the light-emitting layers 1 through 3 comprises a phosphor layer with an insulating layer disposed on one side thereof or on each of opposite sides thereof. The phosphor layer may be made of a base material such as ZnS, ZnSe, SrS, CaS, SrSe, CaSe, or any of their liquid crystals. Each of the light-emitting layers contains a central light-emitting material such as Mn or a lanthanum-base rare earth material. The insulating layer may be made of an oxide such as Y_2O_3, SiO_2, Al_2O_3, or Ta_2O_5, a nitride such as Si_3N_4, a tungsten-bronze-base ferrodielectric substance, or a perovskite-base ferrodielectric substance. The insulating layer may also be made of any of multilayer composite films, mixed crystals, and solid solutions of these materials. On opposite sides of the light-emitting layers 1 through 3, there are disposed line sequential driving scanning electrodes 4 through 6 and display electrodes 7 through 9. The electrodes 5 through 9 except the scanning electrode 4 which serves as a back electrode are all in the form of transparent electrodes made of an ITO- or ZnO-base material. The light-emitting layers 1 through 3, and the scanning electrodes 4 through 6 and the display electrodes 7 through 9 on opposite sides of the light-emitting layers jointly constitute respective independent units which are electrically isolated from each other by insulating layers 10, 11. The insulating layer 10 isolates the display electrode 7 and the scanning electrode 5 from each other to eliminate influences of variations in the electric field distribution due to switching on and off of these electrodes, the insulating layer 10 having sufficient transparency to light. The insulating layer 11 isolates the display electrode 8 and the scanning electrode 6 from each other and has sufficient transparency to light.

A data signal A, a data signal S, a data signal C, a data transfer clock signal CK, a horizontal synchronizing signal HD, and a vertical synchronizing signal VD are applied from a display control system to a control circuit 12 in which the signals are temporarily stored. The signals are then controlled in timing for line sequential driving and distributed to modulator/drivers (power supply circuits) 13 through 18 and driver ICs (integrated circuits) 19 through 24. The modulator/drivers 13 through 18 are responsive to the input signals from the control circuit 12 for generating power supply voltages to be applied to the electrodes 4 through 9 and sending the generated power supply voltages to the driver ICs 19 through 24. The driver ICs 19 through 24 is in response to timing commands from the control circuit 12 for applying the power supply voltages from the modulator/drivers 13 through 18 to the electrodes 4 through 9. In FIG. 2, Y and X represent the scanning and display electrodes, respectively, and A, B and C represent the light-emitting layers 1 through 3, respectively.

FIG. 1 shows a device for producing a multiplicity of colors according to an embodiment of the present invention. The device has light-emitting layers 1 through 3, scanning electrodes 25 associated with the light-emitting layer 1, scanning electrodes 26 associated with the light-emitting layers 2, 3, display

electrodes 27 associated with the light-emitting layers 1, 2, and display electrodes 28 associated with the light-emitting layer 3. The electrodes 25 through 28 and the light-emitting layers 1 through 3 are stacked into an electroluminescent display. The light-emitting layers 1 through 3 may be made of the same material as that of the light-emitting layers 1 through 3 shown in FIG. 2, and the electrodes 25 through 28 may be made of the same material as that of the electrodes 4 through 9 shown in FIG. 2. The electroluminescent display illustrated in FIG. 1 differs primarily from that of FIG. 2 in that those electrodes disposed between the light-emitting layers are shared thereby and any insulating layers for isolating the units including the light-emitting layers are thereby dispensed with.

The electroluminescent display of FIG. 1 is in the form of a panel 36 as shown in FIG. 3. The electrodes 25 through 28 are arranged in a matrix pattern and connected to driver ICs 29 through 32, respectively. The driver ICs 29 through 32 may be disposed in vertically and horizontally confronting relation, as illustrated in FIG. 3, or may be positioned on one side of the display panel 36. The driver ICs 29 through 32 may be arranged in any of various ways without limitations; for example, ICs of one type may be put together at respective odd-numbered and even-numbered addresses and disposed in confronting relation.

FIG. 4 is a timing chart explaining a method of driving the electroluminescent display where N scanning lines and n display lines are involved. "on" and "off" in FIG. 4 indicate switching on and off, respectively, of the driver ICs. In a first step, the driver ICs 29, 31 are driven in a line sequential mode to enable the light-emitting layer 1 to form one frame picture (picture A) which may be a red picture, for example. Then, in a second step, the driver ICs 30, 31 are driven in a line sequential mode to enable the light-emitting layer 2 to form one frame picture (picture B) which may be a green picture, for example. In a final third step, the driver ICs 30, 32 are driven in a line sequential mode to enable the light-emitting layer 3 to form one frame picture (picture C) which may be a blue picture, for example. The three color-separated pictures thus serially formed are combined on a time basis into one composite color picture.

The pictures A, B, C are sequentially displayed in repetitive cycles at a frequency called a frame frequency. When the frame frquency is higher than the crical fusion or flicker frequency (CFFF) of color stimulus for human beings, the colors of the pictures appear sufficiently mixed to the human eyes. If the frame frequency is higher than the range of from 40 to 50 Hz, then composite multicolor pictures of good color reproducibility can be obtained.

A data signal A, a data signal B, a data signal C, a data transfer clock signal CK, a horizontal synchronizing signal HD, and a vertical synchronizing signal VD are applied from a display control system to a control circuit 33 in the same manner as shown in FIG. 2. This input application is the minimum requirement to be met in order to make the device of FIG. 1 compatible with the conventional device. These signals are temporarily stored in the control circuit 33, and then sequentially supplied to modulator/drivers 34, 35 and the driver ICs 29 through 32 at the timing of FIG. 4. Since some of the electrodes sandwiched by the light-emitting layers are shared by the light-emitting layers, only four kinds of electrodes 25 through 28 are required, and hence the number of driver ICs used is reduced to 2/3 of the number of driver ICs used in the device shown in FIG. 2.

As illustrated in FIG. 4, the scanning signals and the display signals are applied fully in a serial fashion from the first through third steps. This means that only one modulator/-driver suffices for each of the scanning and display electrode sets. The power supply voltage supplied to each of the electrode layers is controlled by only a timing command applied from the control circuit 33 to the corresponding driver IC, and no problem arises from the wiring arrangement shown in FIG. 1. More specifically, the modulator/driver 34 applies a power supply voltage to the driver ICs 29, 30, and the modulator/ driver 35 applies a power supply voltage to the driver ICs 31, 32. The driver ICs 29 through 32 supply the applied power supply voltage to the electrodes 25 through 28 according to timing commands from the control circuit 33. This manner of applying the power supply voltage remains the same irrespective of whether the electrode ends are floated or ground when the driver ICs 29 through 32 are switched of f. Therefore, the number of modulator/drivers used is reduced to 1/3 of the number of modulator/drivers employed in the conventional device shown in FIG. 2.

As a result, the number of components of the device is greatly reduced.

As is apparent from the timing chart of FIG. 4, the data signal C supplied to the control circuit 33 may have to be retained in a maximum of two frame periods. Therefore, a memory having a storage capacity which is three times greater than that of the memory in the device of FIG. 2 is required to store the data signal C. Use of such a larger-capacity memory, however, does not cause a significant problem. Nevertheless, by shifting periods for sampling the data signals as shown in FIG. 6, the data signals may be retained in the same conditions as those for FIG. 2, and no increase in the storage capacity is needed. It has been found that by shifting the data sampling periods, the data signals can be sampled in a serial manner, and hence ad-

dresses in the memory can be used again, so that the storage capacity may be 1/3 of that of the memory in the device shown in FIG. 2.

As described above, where the frame frequency at which the pictures A, B, C are sequentially repeated is higher than 40 to 50 Hz, the colors of the respective pictures A, B, C appear to be well mixed to the human eyes.

Conditions for preventing flickering with respect to brightness in displaying images will be described below.

Assuming that the frame frequency of sequential repetition of the pictures A, B, C is indicated by Ff and a frequency of repeating a multicolor picture composed of frames of pictures A, B, C is indicated by Fm, these frequencies are related to each other as $3Fm \doteqdot Ff$. Ff is the same as $1/tF$, and $Fm = 1/\Delta T$. It was experimentally confirmed using the device of the invention that Fm should be higher than 30 Hz in order to completely eliminate flickering with respect to time-dependent changes in brightness. This result seems reasonable since the critical fusion or flicker frequency of brightness in the sense of sight of human beings ranges from 30 to 50 Hz.

From the relationship between Fm and Ff, it is understood that where there are three light-emitting layers, the frequency Ff should be higher than 90 Hz in order to eliminate flickering with respect to time-dependent changes in brightness. This requirement also meets the color mixing condition: $Ff > 40$ through 50 Hz as described above. Therefore, a sufficient color mixing ef fect is obtained by selecting Ff to be over 90 Hz. Heretofore, the general frame frequency has been in the range of from 50 to 60 Hz, failing to fully preventing flickering in displaying images including moving images. With $Ff > 90$ according to the present invention, flickering can be prevented irrespective of whether displayed images are still or moving.

The frame frequency over 90 Hz is a high frequency which would make it difficult for images to be displayed in good response. However, the thin-film electroluminescent display including phosphorous layers suffers no signif icant problem as to display response. No problem would also be experienced even by adding a brightness modulation circuit of the amplitude, pulse duration, frequency, or phase modulation type to the display driver system.

It is necessary to add a reverse voltage application mode for reproducing images while eliminating a remaining electric field in a light-emitting layer. This can be effected by applying a reverse voltage pulse to all pixels immediately before or after each frame, or applying a reverse voltage pulse to the pixels each time a scanning line is selected, or reversing a light-emitting voltage pulse in each frame. Any of these processes is applicable to the present invention.

While the present invention has been described with reference to an electroluminescent display, the principles of the present invention are also applicable to a fluorescent display tube, a plasma display, or the like.

Although a certain preferred embodiment has been shown and described, it should be understood that many changes and modif ications may be made therein without departing from the scope of the appended claims.

CLAIMS

1. A method of producing a multiplicity of colors on a multicolor display having pixels, comprising the step of sequentially varying the colors of lights from the pixels repeatedly on a time basis in response to display signals at a repetition frequency higher than a critical fusion frequency of color stimulus for thereby enabling the sequentially varying colors to appear to be mixed.

2. A device for producing a multiplicity of colors comprising a plurality of stacked light-emitting layers capable of emitting lights of mutually different colors, a plurality of display electrodes and scanning electrodes disposed on opposite sides of each of said light-emitting layers, those electrodes which are interposed between the light-emitting layers being shared as electrodes for driving the light-emitting layers on opposite sides of those electrodes, and a driver circuit for energizing said display electrodes and said scanning electrodes to cause said light-emitting layers to sequentially display respective frame pictures of the respective colors repeatedly in response to display signals corresponding to the colors of the light-emitting layers, at a repetition frequency higher than a critical fusion frequency of color stimulus.

3. A device for producing a multiplicity of colors comprising a plurality of stacked light-emitting layers capable of emitting lights of mutually different colors, a plurality of display electrodes and scanning electrodes disposed on opposite sides of each of said light-emitting layers, those electrodes which are interposed between the light-emitting layers being shared as electrodes for driving the light-emitting layers on opposite sides of those electrodes, and a driver circuit for energizing said display electrodes and said scanning electrodes to cause said light-emitting layers to sequentially display respective frame pictures of the respective colors repeatedly in response to display signals corresponding to the colors of the light-emitting layers, at a repetition frequency higher than a critical fusion frequency of color stimulus, for thereby producing a multicolor picture, and for repeating the multicolor picture at a frequency higher than a critical fusion frequency of brightness, for thereby producing a moving multicolor picture.

4. A device according to claim 3, wherein said frequency at which the multicolor picture is repeated is higher than 30 Hz.

5. A method of producing a multiplicity of colors on a multicolor display substantially as hereinbefore described with reference to Claim 1.

6. A device for producing a multiplicity of colors substantially as hereinbefore described with reference to Figure 1 and Figures 3 to 5 of the accompanying drawings.

Published 1988 at The Patent Office, State House, 66/71 High Holborn, London WC1R 4TP. Further copies may be obtained from The Patent Office, Sales Branch, St Mary Cray, Orpington, Kent BR5 3RD. Printed by Burgess & Son (Abingdon) Ltd. Con. 1/87.